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THE DEVELOPMENT OF EFFICIENT METHODS IN THE FOUNDRY.

Paper presented to the Institution, Coventry Section, 3rd December, 1930, by E. M. Currie.

THE following paper is not intended as a contribution to founding literature, but rather to form the basis of a discussion. To develop the subject matter conveyed by the title of my lecture to the full, the time at my disposal would be far too short, so that while outlining many, I can only fully go into the main principles of one or two foundry operations. The present century and the latter end of the last one, are remarkable for the wonderful inventions that are crowding one on the other, all of which have necessitated continual changes in the class and design of castings needed. Practically every other branch of industrial enterprise has met and kept pace with these improvements. The modern foundry to-day, it is true, has done much towards falling into line mechanically, and the use of production equipment and labour saving appliances is becoming widespread. There are, unfortunately, only too few of these modern foundries. The great majority are content to struggle along on rule of thumb methods.

They were remarkable in their age for the wonderful achievements and difficulties overcome. But yesterday is not to-day in the forward march of progress. Accuse any founder of vacillation and lassitude, and he would indignantly deny the charge. Point out the improvements that are being made in other quarters, and he would unhesitatingly agree that these ideas are splendid for other people, but that they could not possibly be applied or adapted in any way to *his* work, because of this or that procedure peculiar to his own plant, and having said what is to his mind the final word, he then dismisses the subject entirely from his thoughts.

It is partly this attitude that has succeeded in crippling sections of the industry and delaying progress towards greater output, better quality and increased earnings all round—in other words, efficiency in its widest sense. Possibly in other trades, but most certainly in the foundry industry, do we hesitate to take advantage of experience developed and proved in kindred trades. We have the excuse that foundry work is a trade in which, in particular, routine responsibilities tie us down ; that we have no time to study, in any other than a haphazard way, improved methods of working.

A brief extract from the history of the art of ironfounding is illuminating, as it shows at one point the reaction of founders to new and revolutionary ideas. We know that as far back as the end of the stone age, bronze was introduced. This bronze consisted of an impure copper hardened accidentally by the impurities of sulphur, iron or arsenic. Later, when tin was discovered, its value was recognised and used with the copper. We find mention of brass founding in the early chapters of the Bible and in the Biblical wars the use of iron is also noted. From the East, it is probable that nomadic tribes carried their knowledge of working metals across Europe and introduced iron smelting into England, where they found very rich deposits of ores. The Romans, on their arrival, found the metal already known to the Britons who only worked the processes when necessary, in order to acquire weapons or to barter for other goods. The industry of the Roman colonists altered this system of working and when they finally left Britain they also left behind them immense mounds of cinder as a monument of their work. Large quantities of wrought iron were produced by a process of simple reduction from the ore: and with a slight modification, the smelters were able to produce a crude steel. In the fourteenth century, the iron trade of England was seriously crippled by the scarcity of charcoal, the fuel used for smelting, and for two centuries work was practically at a standstill. The exact date at which cast iron was first produced is unknown, but towards the end of the fourteenth century, owing probably to attempts to speed up the process, the furnace operators found that their metals became molten. At first they were heavily penalised for thus wasting the charge and fuel, but later it was found that the new

material made excellent cannon balls. After this, cast iron guns and war materials of this description were made in increasing quantities.

Acts of Parliament passed for the protection of the forests compelled the ironfounders to seek other methods of smelting. Hitherto prosperous works were plunged into a period of depression from which many of them never recovered. Coal had been known and used in England as early as the tenth century, but had never entered into serious competition with wood as a fuel. It is an amazing example of shortsightedness that when faced with the problem of obtaining supplies of charcoal the early manufacturers were so obstinate in their belief that it was the only fuel for reducing the ore, that in 1620 when Dud Dudley began working his patent (adaption of coal as a fuel by turning it into a crude form of coke) he was so successful that the charcoal exponents instigated riots that wrecked his works. Until Abraham Darby commenced his successful works at Coalbrookdale in Shropshire, and eventually adapted the smelting of iron with coal, nothing much had been done for well over a hundred years. Many were the problems which confronted this famous ironmaster, but by persistent energy he wrested secret after secret in the art of making castings in cast iron, and to-day the basic principles of his discoveries are still being used in much the same way. For example, up to that time, moulds had been made of clay, which more often than not cracked and burst. Darby had learnt that brass had been successfully cast into sand in Holland, but it was not until after years of patient experimenting that success crowned his efforts.

Another development was the method of leading away the gases generated during the casting. To-day we vent the moulds and cores in much the same manner as Darby did then. Some of the most recent developments, especially in America where sand problems are studied of necessity, far more than they are over here, are leading towards a complete self-venting sand, thus making a considerable saving in time on this operation. Improvements now followed thick and fast, and the iron trade entered on a period of unprecedented prosperity.

While this necessarily brief resumé is intended to outline part of the history of founding, it also serves to show the immense difficulties that were overcome by the doggedness and genius of certain men, and the attitude of others, less foreseeing, which made them decidely obstructive. The ideas were apparent then, but policy forbade them to profit. Considered as a whole, the foundry presents no greater difficulties for the application of improved methods of production than any other industry. I propose to show in the following few slides a comparison between old methods still extant and more modern methods.

Definition usually implies a limitation, but I am going to attempt

to define what I mean by efficiency—*it is the controlled application of progress to ensure greater results.* Many of the older methods you have just seen could have been made more efficient in their limited way, but *that* would not be progress. Much of the more modern machinery is not effective *on its own.* It is when control is applied that efficiency comes to the front.

The progressive foundry of to-day owes its position to the application of control in many of its operations. Let us take, for example, the cupolas. In this furnace we are able to melt several mixtures of varying compositions to suit the various types of castings. Each grade and each brand of pig iron, as produced at the blast furnaces, have different characteristics that make them eminently suitable for different types of castings. A combination of certain of these irons, selected to give the right composition for the section of metal and purpose of the casting, is put into the cupola. Thus we get the first control. The composition determines the freezing period of the iron. Generally, the softer the iron the longer the period, and the harder the iron the shorter the period. As it is at this point that porosity and shrinkage take place you will readily understand how important is composition in this respect.

We consider then, when determining a composition, strength and solidity, fluidity, and the purpose of the casting, whether for machinery, automobile cylinders, and castings for marine engineering, pressure castings, acid and heat resisting castings, hydraulic work, or metal for hard wearing such as for rolls, etc. In melting practice control does not end here,—the amount and quality of the coke, the use of a flux, volume and pressure of air necessary to ensure the correct combustion of the fuel so that hot and fluid metal is obtained. Properly run, the cupola gives wonderful uniformity of results and any class and any purpose of iron can be melted.

(*Slides were shown here illustrating the working of the furnace*).

Defectives are only too easily produced in the foundry, as any executive will readily agree. When one considers the number of variables that exists, and may and do cause trouble, it becomes at once apparent that control is absolutely necessary. Rule of thumb methods must be completely eliminated and the efficient supervisor now makes full use of sand preparation and handling equipment, efficient drying stoves and properly supervised moulding, coring and casting operations.

Sands and similar deposits are the results of disintegration of rocks by the geological agencies of the sun's heat, frost and rain. Fragments of rock in this continual movement are reduced in size by wear and tear, by chemical as well as mechanical action, and are broken up into their constituent mineral grains. Sands used by the metallurgical industry may be classified into three groups, for each of which materials somewhat different properties are

required. (1) High silicon sands for furnace hearths and crucible making ; (2) sands for different varieties of bricks ; (3) sands for preparing the moulds in which iron, steel, brass and other metals are cast.

It is with the latter class that we are mainly concerned in the foundry. This sand is mixed with other materials, such as chaff, manure, coal dust, etc., to form the different grades that are used in the foundry. The effective mixing of sand mixtures is of the greatest importance, and it is also a very difficult matter to mix effectively. No forms of mixing machines are perfection, so we must compromise and pay close attention to the mixture required and the available means we have to attain the best possible results. The practical man endeavours to obtain the most economical mixture with the most suitable sand. It should be strong and cohesive, to take the shape of the pattern and resist the wash of the molten metal, and to avoid losing the most important property of the sand, its permeability ; the power of the sand to allow the passage of gases generated during the pouring of the metal.

(*Slides were shown here illustrating types of sand-mixing machinery each with different features and each giving different results*).

Although a good deal of my previous and ensuing remarks deal with grey iron, it must not be thought that it is on this branch alone that any censure that accrues may be passed. Steel, non-ferrous and malleable foundries are equally concerned. The basic principles of these are identical with those of grey iron founding.

At this point it would be as well to consider in which direction the foundry *has* advanced. The modern foundry of to-day, is no doubt tending towards the mechanisation of many of its processes. How far one may go in this direction is a debatable point. The restriction of the human element with the advancement of mechanisation is a step that will end in disaster. Both have to be carefully balanced, the one considered just as much as the other, and neither to the entire exclusion of each other. Specialisation of the workman by mechanisation tends to destroy pride in craftsmanship. There are so many various ways in which a faulty casting can be made and it is fatally easy for the human element to wreck the preconceived idea, that unless the particular workman can be held directly responsible for his section of work, the quality and standard of the product is bound to suffer.

New moulding machinery, cranes, furnaces, sand-mixing machinery, metal transport equipment, and a host of other improvements are continually being designed and adopted, new methods and systems of working, better costing, recording and selling systems are gradually being brought into operation, but unfortunately far too slowly is their full worth being recognised by many founders.

On the metallurgical side, we to-day have a much better appreciation of the limitation of the materials that we must employ.

This realisation is the foundation on which improvements are being made. To take in particular cast iron. We agree that it lacks toughness and ductility, that it will not withstand very severe shocks and stresses. Within the last twenty years commercial grades are gradually being replaced by high duty grades made by variations of the usual method of production in furnace and mould, or by the introduction of special elements. For high duty irons the amount of carbon in the iron must be kept within definite limits, and it has also been proved that this figure does not depend wholly on the carbon content of the irons charged into the furnace, but more upon the cupola control. In some mixtures steel scrap is added. This absorbs carbon from the incandescent coke in its descent through the furnace and would, unless controlled, absorb a considerable quantity. To retain the useful characteristics imported by the steel additions, the amount of air entering the furnace is varied. A hot fluid iron is produced when the correct volume of air combines with the coke to give a very slight oxidising atmosphere and fairly low blast pressure.

With the carbon on the low side strengths are obtained in the casting. Perhaps the most important element in cast iron is silicon. Its effect on the structure and the form of the carbon has been studied intently. High duty cast irons depend for their strength on the control of the separated graphite flakes, which of course, weaken the internal crystalline structure and high silicon contents invariably aid the graphitisation of the iron. The reduction in size of the graphite flakes is the method by which quality in iron is obtained.

Temperature control, as with the production of pearlitic iron, in which the composition of elements is kept a definite amount (Si C. 3.9—4.5 Mn .7—.8), produced an extremely tough iron. The moulds are heated and the iron poured into them. If iron of this composition were poured into an ordinary mould it would be hard, brittle and unmachinable. Pearlitic iron on the other hand is perfectly machinable, slightly ductile and does not grow when repeatedly heated and cooled, and its tensile strength is approximately twenty-two tons per square inch. Superheating the molten iron to 1,600° C. has the effect of improving the tensile strength by dissolving the free carbon in the iron.

Alloys of cast iron made with nickel, chromium, molybdenum, copper, vanadium and titanium, all tend towards improving or modifying the iron. Chromium combines with the carbon in the iron and produces an iron which is hard and resistant to abrasion and raises the tensile strength of the iron by its degraphitising effect. This property is required for crushing mills, ball mills (2.00 per cent. Cr, .8 per cent. Si, .6 per cent. Mn) and chilled rolls. Additions of three per cent. Cr aids resistance to corrosions by

various acids. Nickel is used as an addition to iron containing chromium and effects improvements in the transverse strength. By careful adjustment of the proportions of nickel, chromium and silicon iron of twenty-eight tons tensile and nearly two and a half tons transverse have been reported when made under special conditions.

The alteration to the physical structure of the resultant iron has produced a material capable of a wider application in commerce and there is no doubt whatever that considerable progress is still being made in the same direction, although we know a good deal of our knowledge is still incomplete, both metallurgically and mechanically. The production of the perfect casting each time is still too much of a gamble.

The metal in the ladle is produced as near a standard as possible considering the variation of pig iron, coke, limestone, scrap conditions and furnace operations. Then it is poured into a mould which, owing to the shape of the casting, is of a plastic refractory material containing huge quantities of gas, will liberate steam in addition, erodes in the metal stream, and owing to complexities of design complicates the shrinkage problems, so that feeding heads, runners, risers and chills must be attached, of such size and shape that the castings when produced are as near being perfectly sound as it is possible to make them.

Although progress has been made very rapidly in some directions it is realised that a great number of fundamental details are at the best imperfectly understood, and until this state of affairs is altered real progress will be delayed. The average foundry of to-day is a strange mixture of new ideas and obsolete methods, a jumble of old and new machinery, old men with old ideas, young men with young ideas—all clashing—a real problem.

There is a tendency to pay more attention to the metallurgical side of the business rather than to shop practice, this being usually left to the skill and discretion of the men in charge of the shop. A wrong policy. In some cases, not even this is done. A weak foreman will allow his men to decide for him. To depend on the tradesman or mechanic as the source of progress can only result in limited advancement. In the old fashioned way, every workman had his own methods. He selected and sharpened his own tools, the moulder mixed his own sand, the pattern maker had to saw off his own wood, and in general the men were expected to know their own job from bottom to top. Some did, but most did not. Scientific management has altered all this. Work is studied, the planning department steps in, and to-day nothing is left entirely to the worker himself. Guesswork and haphazard methods have been abolished, and a good deal of the work of the factory is now being done by the management through the use of the planning departments and specialists, all

through the works. To-day, the leading firms with foundries are having men technically trained to the problem of shop practice and creating the foundry engineer. This is the correct road to progress. Having time to study, not being tied down by routine responsibilities or viewing every improvement from the standpoint of affecting his own work, he is of real value. He would even, in conjunction with the production engineer, form the planning department, so that the best, most up-to-date and speedy methods of manufacturing for a given product be planned beforehand from start to finish, with a reasonable certainty of method, thus eliminating waste and misguided effort, all of which must be paid for, both by the manufacturer and the workmen.

A really scientific investigation of the best method of working should be studied. Then it is essential that the foreman or the man in charge should be in sympathy, and trained thoroughly in all the new moves before his men are trained, as antagonism in this quarter is generally fatal. The attitude of the foreman is often the policy to be adopted by his men.

Good management usually means success, and good management through efficient planning is the keynote of progress. Planning, I am quite aware is only *one* aspect of management, but it is not the least important. Efficient planning controls and develops the output, brings out new ideas, steadies the costs and determines the best possible methods for a definite programme, which in the end certainly leads to increased profits all round.

There is an idea prevalent that modern high speed production affects the quality of the finished product. That the introduction of these methods is eliminating the skilled workman, and that without these many articles of good quality cannot be produced. Quantity production can also mean quality production. The result depends on the way the craftsman is brought to the new methods. At the same time, as the machinery is developed, the man should be developed also, that is, the man should be efficiently trained to the definite job. That is the point at which so many really modern organisations fail. After installing new and up-to-date machinery, mixing plants, etc., that vital link, the human element, is unconsidered. The result is that the man underestimates his ability to deal with this plant as it should be handled, he does not realise to the full that it is up to him to use his own initiative on the work in order to increase the production, lower the cost, and also, of more direct benefit to himself, increased earning power. With the right process, the correct raw materials, trained men and a system of inspection that ensures the maintenance of standards, quality production will ensure quality products.

In conclusion I must acknowledge my indebtedness to the following: Messrs. Alfred Herbert, Ltd., Coventry, Messrs. Morris and

Company, Loughborough, Foundry Plant and Machinery, Ltd., Glasgow, Fordath Engineering Company, West Bromwich, and Stanton Ironworks, Ltd., Nottingham, for assistance rendered in the preparation of the lantern slides.

Discussion.

MR. TWIGGER: In one thing I fully bear you out, and that is the number of developments which have come along during the past few years. It is a commonplace that in all the things of life, these last twenty-five years have probably produced more changes than in any other twenty-five years in the history of this country. That is most certainly true in the case of foundry work, and I speak more in regard to cast iron. It is bewildering when one thinks of all the special types of cast iron which have been introduced in recent years, together with the vast range which has opened up by the heat treatment of cast iron. One sometimes wonders where it is going to end. It is quite certain that more and more factors will have to be brought into the reckoning if we are to maintain a consistently high quality. In regard to the improvement of quality, while at the same time reducing costs by mass production methods; this may be quite possible, and the ideal to which everyone must strive, but there has been a tendency for a long time on the part of engineers, to look upon cast iron as something which they must have, but which after all, is not very reliable, and in any case is something which must be produced cheaply. The demand for increased quality is becoming insistent, and I think it is necessary to warn engineers, that while the cost of increased quality of material may be offset to a certain extent by cheaper production methods, there are many cases in which it is not possible to overcome increase in cost entirely, and that if they want a better job they will probably have to pay more for it. There is little or no organisation amongst manufacturers in the foundry trade, consequently to-day the prices are cut to the lowest possible figure, and the tendency is, among engineers and buyers, to go right out for the cheapest market. If they really knew the cost of the extra scrap and perhaps the extra machining operations required, they would not hesitate to co-operate with the foundry, who specialise perhaps in that particular line, even though it meant paying a little more for their castings. The very big question which comes in in connection with the installation of all the mechanical handling devices such as we saw, is that of capital cost and upkeep. These devices have, of course, been very largely developed in America. It is difficult in this country, particularly when one is associated with a small unit, to know how far to go in that direction, because the capital cost and depreciation of a small unit will be very disproportionate as compared with the cost in a large foundry. In

conclusion, there are one or two questions I would like to ask. As regards charging of cupolas, have you had any experience, and do you really find that the pig iron and coke are distributed quite well in the cupola from these discharging devices, say in small cupolas twenty-five to thirty inches in diameter? The control of sand is, to my mind, a very important matter, but it seemed difficult to evolve simple practical tests which could be applied daily in the foundry. In regard to the temperature of molten iron, there are some classes of work for which careful control of temperature is essential, but to get some means of measuring the temperature, even in a comparative way, is one of the most difficult jobs I have attempted. Any information on this point would be appreciated.

MR. CURRIE: I am very glad to find that you are in complete agreement with a great many of the things I have said. You evidently know the difficulties with which foundrymen have to contend. I am glad to find that you have thought fit to issue a warning to engineers, that any demand for increased quality must be met with increased cost. Until we can really get down to these metallurgical developments and the advances of mechanical handling to save labour and cost, at the present moment it must be met by increased cost. On the question of mechanical charging of cupolas, I do not advocate this for small cupolas, as it is difficult evenly to spread the charge. The devices you have seen to-night have been applied to cupolas not less than forty inches internal diameter. The melting rate would be about ten tons per hour. A small cupola about twenty-five inches will only melt between two and a half to three tons per hour, and mechanical handling is not wanted. Charging by hand will more than satisfy the demands of this cupola. In regard to sand testing, there is no doubt that this must be done if the sand is to be maintained at even quality, especially in foundries using a sand-preparing plant and semi-skilled labour. The British Cast Iron Research Association has recently developed certain methods for testing sand in a practical and efficient manner. I am afraid that I cannot say a lot about temperature control at the moment. It is a difficult matter, but modern methods are now coming in, by means of which temperature control and melting operations can be carried out with more reasonable certainty than with the cupola. I am referring now to pulverised fuel rotary furnaces.

MR. RILEY: Mechanical handling, particularly in regard to the slinger. You mentioned the slinger in connection with moulds. Can that be applied to the production of cores, or does the necessary venting of cores prevent this? Is the permeability of the sand sufficient? In regard to centrifugal casting of pipes in a permanent mould, the question of the chilling effect of the mould arose in my mind against that of the sand. Are any precautions taken to prevent the chilling of the iron? You mentioned the introduction

of nickel, chromium, etc., but you did not mention anything in regard to impurities such as sulphur, which I understand is rather a bad point with foundrymen. I should like your opinion on the permissible limits which are allowed to be present in the iron, and the general effect on the strength and porosity of the iron.

MR. CURRIE: The sand slinger can be applied to core making, but here you come upon a greater difficulty than is usual in handling moulds. With a good many boxes you have undercut pieces, and naturally a device which rams by throwing sand from the top, is not going to get underneath. Venting is partly accomplished by air intermingling with the sand, and in the usual way with a vent wire. In regard to centrifugal casting, chilling does take place on these pipes. The composition of the iron is controlled to give a definite strength in the casting, and at the same time to minimise the chilling effect. I showed a slide of three test bars broken at the end, and one—a very soft iron—showed very little chill indeed. Any chill formed by the use of a cast iron or steel mould is removed by means of an annealing operation, following the extraction of the pipe. This annealing operation takes place at a temperature of 900° C. for about one hour in a continuous furnace. This removes any brittleness or strains and chill on the casting, due to casting it in a permanent mould. I purposely did not mention sulphur. This is probably one of the most troublesome elements we have to deal with. In regard to the limits of sulphur in cast iron, in some castings it is distinctly harmful, but in others it is not. For instance, a great many people here to-night are interested in motor cylinder work. Sulphur there, in cast iron is a distinctly harmful element, whilst in chill rolls a far higher percentage is not detrimental. Sulphur causes brittleness.

MR. PEARCE: In regard to castings, I would like to say that these are being produced by the centrifugal method in Coventry at the rate of about thirty tons per week. We are able to produce very good ones, easily machined, without any annealing whatever. It is true that in the foundry great and rapid strides have been made of late years, and I hold the view that hindrances are imposed on us by designers. Wherever there is sufficient volume of work to pay, the foundryman can get to within close limits. We speak very often in thousandths of an inch, we even work to gauges which have a tolerance of ten-thousandths of an inch. I claim that wherever there is sufficient volume of work at hand, the foundryman can get down to it and make the job pay. We are able, by means of sand slingers and other things, to produce well. If engineers could make their designs uniform it would help considerably.

MR. CURRIE: I am very glad that you have added your word to mine. The natural enemy of the foundryman appears to be the designer. We cannot persuade them to leave beauty of form alone

and concentrate more on even thicknesses of metal to help us with our complications. There is no doubt that the designer can easily produce a sensible job. With the risk of giving offence, I should like to say that they certainly can, by every means in their power, help us more by giving even thicknesses of metal, and make our work far easier than it is.

MR. AIERS: Have you used X-rays for the detection of flaws in castings? I should also like some information on the self-venting sands they are using in America. In walking round foundries, one notices that the various boxes, etc., are made of heavy cast iron, well ribbed up. Is this because the foundrymen are very strong? I should have thought they could use aluminium or some metal lighter than cast iron.

MR. CURRIE: This point is receiving the attention to-day of a good many metallurgists. The use of X-rays requires a specialist, and that is going to increase cost. Secondly, the use of X-rays is only of sufficient value up to certain thicknesses of castings, and in a great many cases it is going to be difficult to prove just whether a flaw in a certain place is going to be harmful or not. We take a casting to-day, and examined externally it looks perfectly sound. None but a foundryman would like to say that. It is not absolutely certain that everything is as it should be, and naturally, progress in this direction depends on help from the foundry. If this develops and our inspectors are provided with X-rays, there is no knowing where it will end. I should not welcome it. There are certain things I like to keep to myself. In regard to self-venting sands, in America freightage costs are rather high, and most foundries endeavour to use materials which lie at their door. If they have to set about the making of a synthetic sand they are able to mix with it other sands in order to develop the property of permeability and so save time on the operation of venting. In regard to cast iron boxes being strong. These boxes cost a good deal of money to make, and naturally we do not want them to crack or go under after being used only once or twice. If the boxes are made of aluminium, the possibility of springing would cause one to obtain a deformed casting

A VISITOR: You have shown us to-night some very interesting mechanical devices intended for foundry use, and at the outset you said that there are still a large number of foundries working on their antiquated systems. I suggest that this machinery or these modern installations that are being put in foundries to-day, have a considerable disadvantage in their application to these antiquated foundries, the construction and design of these foundries not being suitable. Do you agree with that?

MR. CURRIE: There is no doubt that the old fashioned type of foundry is not altogether suited for the installation of modern conveying machinery, but you can go a step in that direction by using a gravity track to a certain extent for conveying moulds.

Overhead track for conveying sand is not everything in mechanisation. A great deal can be done on the floor, and in this way gravity track and conveyors are very useful.

A VISITOR: You stressed the desirability of using these on account of the uniformity obtained in results, especially in regard to the uniformity of mixing. Can you state that where these machines are in use, a definite reduction is obtained in the percentage of scrap which even the best foundries suffer from? In addition, you spent quite a time on sands, mixing, etc. Do you think it would be desirable for actual casting machines such as are in use at present, to be introduced more generally in England than they are? Do you think the standard quality of the work would be better by the more complete elimination of the human element than at present?

MR. CURRIE: I think that the quality of the casting, especially when made under partly mechanical conditions, is bound to be better to a certain extent than that made by hand. There is no doubt that mechanisation produces uniformity of work, and all this tends towards the elimination of scrap. There are certain operations which we cannot mechanise. When we come to consider foundries making one-off castings, mechanisation here is not going to help, but when we turn to the United States, which is the great centre of mechanisation, we find a tendency to eliminate all these one-off castings. Each foundry specialises on one or two types of castings. All this is a direct help towards mechanisation. In America the recent development of doing away with this one-off business is towards welded steel structures, and the welded steel structure is a rather poor substitute for a homogeneous casting. It is certainly lighter, but its shape leaves a great deal to be desired.

MR. WEEKES: Ever since I can remember having anything to do with lectures, the foundryman usually trots out the bogey of the designer, and looks upon him as his natural enemy. In regard to the mechanising of foundries, I think that in this country the chief reason why we do not have many foundries with up-to-date mechanical appliances is due to the fact that they are usually and principally small foundries. I think that what Mr. Currie would like to see here is some organisation similar to that of Messrs. Guest, Keen and Nettlefolds. Many years ago they got automatic machinery and cut their prices so fine that men working in the old fashioned way were compelled to sell their businesses to this huge combine, or get out of the business. If something like that could be done, I am quite sure that we should not have to look to America to see foundries mechanised and turning out the best castings in large quantities. America would no doubt soon have to look to the Old Country, and all would be well.

MR. CURRIE: Mr. Weekes has certainly mentioned the Utopia of the foundry trade, and I do not think I can add a lot more to his remarks in this direction.

A VISITOR: In regard to density, we control, condense and get certain forms of crystals in castings. Is the density controlled by the method of running?

MR. CURRIE: Runners and risers of a casting certainly have an effect on the density, but in the foundry we have to be careful where we place these. In test bars, we attempt to obtain each day a standard method of preparation, so that the results are standard, and thereby we can judge in what way any variation that takes place in actual practice is going to affect them. Runners and risers are always a point on which we have to be very careful—they have to be placed at definite parts of the casting. They are there to help to even up the rates of cooling, the runner to get the metal into the casting, the riser specially to feed and aid the shrinkage problem.

A VISITOR: What in your opinion is the best method of seasoning a casting? Do you consider heat treatment, or rough machining and lying out in the weather?

MR. CURRIE: The longer a casting can be left after rough machining, the better it is for the casting. The strains are eliminated, and it certainly is a better method, but in these days of high production we cannot afford to wait the necessary time, so we have recourse to other methods, viz., annealing.

MR. COLE: The question of production of, say, a cylinder block. Have you had experience of the group method of payment to the men who carry out this work, as against the method of payment of individual operations?

MR. CURRIE: My reply to you is that I am a foundryman, not a cost expert, and to go into detail of the effect on production of group payment as against individual payment is, I am afraid, a little out of the scope of my lecture.

MR. MEACHAM: We have been talking about one-off castings, and the effect of taking them quickly and not allowing them to season. Are there any particular types of castings suitable for quick use, or would it be preferable to use welded jigs for same?

MR. CURRIE: When you come to a question of large castings then you get introduced the problem of the effect of seasoning. On small castings this is not so, and being asked to give an opinion on the different types of castings, it is rather difficult when considering the type of casting one has in mind. Speaking from my own experience of the class of work on which I am engaged, I should prefer to anneal if the casting is required in a very short space of time, but generally speaking, large jigs are made in a very simple manner, consequently, the strains and stresses imposed by casting are not of such a grave nature as one would find in, for instance, a lathe bed, or a heavy casting of that description, especially where it is of box section. Jigs are usually of a simple nature, and are generally built up so that strains and stresses introduced by casting are eliminated in that way.

A VISITOR : The advance in mechanisation in the foundry makes one wonder whether the same atmosphere still prevails as one used to see. Do you think this is all to the good ? Is ventilation considered more than in the old foundries—one would be almost gassed in the old foundries.

MR. CURRIE : I think that from a good many of the slides I have shown, especially those comparing the old methods with the more modern methods, you will see that a great deal of the back-breaking labour is eliminated. Surely this is to the good. If the moulder does not have to shovel and move tons of sand as he has done previously, and puts his skill towards the finishing of the mould, I think all this is to his benefit. The introduction of mechanisation is going to help him to earn more money. I really think that while mechanisation may at the moment cause a great deal of trouble, it is certainly going to benefit civilisation by reducing the cost of the article and placing it within the reach of most of us. The modern foundry of to-day is built with due regard to ventilation. We have better lighting, better ventilation, and in a great many cases better heating. The old-fashioned foundry did not take this sort of thing into account. If we lay out a foundry on modern lines, these are the points to which the plant engineer gives first consideration.

A hearty vote of thanks to Mr. Currie concluded the proceedings.

MODERN TENDENCIES IN MACHINE TOOLS.

Paper presented to the Institution, Manchester Section, 8th December, 1930, by R. C. Fenton (Member).

WHAT more fascinating subject can one have than machine tools, the basis of our engineering achievements, the key which unlocks the vast productions accomplished to-day? Machines ranging from the tiny automatics, weighing only a few pounds, turning out minute screws at hundreds a minute, running at spindle speeds of five thousand revolutions and upwards, to the giant machines for steam and water turbine work, where a casting may remain under operation for weeks on a vertical boring and turning mill, weighing over seven hundred tons, and whose table sometimes revolves as slowly as six times in an hour when operating on work up to seventy-two feet in diameter. In the old days the machine did the job, the time taken was of no great matter, so long as it did it. To-day, seconds count in mass production, and even fractions of seconds to three places of decimals. To keep pace with these demands machine tool builders are ever striving to develop their products, and the object of this lecture is to illustrate to you the lines along which these developments are tending to travel.

In considering these developments we find three governing factors—the human element, the cutter, the product. I place the human element first because so many modern improvements have been evolved solely for its convenience, protection or partial elimination. Try as we may, we cannot entirely dispense with this sometimes undependable element, hence many complicated devices are introduced to protect both man and machine. So under this heading we may classify the following tendencies:

1.—Grouping of controls for the convenience of the operator.

2.—Provision of quick power traverse motions, automatic clamping devices, etc., to prevent undue exertion.

3.—Provision of automatic stops and gauging devices to allow for the varying skill of the operation, and to ensure production being uniform.

4.—Quick change gear boxes to save time and calculations.

5.—Central lubrication systems to guard against the forgetful and to save the time of expensive labour, and the piece worker.

6.—Unit construction for ease in manufacture and repair.

7.—Elimination of overhead gear to give more light and air, and add to the ease of keeping the factory clean.

8.—Provision of guards and safety devices to prevent accidents as much as possible.

The foregoing tendencies refer to general purpose tools. In the case of single or special purpose machines, simplicity is often the keynote, so that the most unskilled of labour can be utilised. Gear boxes give place to pick-off gears, speeds and feeds are fewer, often locked so that they can only be changed by the tool setter, but tooling and work-holding devices are more complicated in construction, though simpler to operate. For instance, " the air chuck," next " the cutter," whether it be turning tool, milling cutter, drill or grinding wheel, that which actually operates upon the work.

There is a state of war between the cutter and the machine. When high speed tool steel was introduced it soon won the first round and the machines were re-designed and re-designed again as the steel makers' art became more perfect. To-day most modern machines can handle high speed steel up to burning point, but tungsten alloy tools have stepped in, and some of our trusty friends are grooving under its increased demands, others have frankly packed up, gears stripped, shafts bent and belts slipping, and so the cutter leads us to :

1.—More power available at the point of cutting, entailing the use of ball and roller bearings, splined shafts, sliding gears in place of clutches.

2.—More rigid slides and tool supports to eliminate vibration.

3.—More speeds and feeds to tune up production.

4.—More cooling lubricant to keep the work and tool from damage, through increased speed of production, and sometimes to remove the cuttings.

5.—Protection of the machine from wear and damage by the extra heavy and sharp cuttings, covered beds, telescopic guards, etc.

6.—Provision of easy clearance and disposal of the chips.

The production job can be said to govern :

1.—The size of the machine, which tends to get bigger and ever bigger.

2.—Greater accuracy to meet the demands for interchangeability, automatic sizing devices and gauging ; this refers more to the automatic machines and not to stops on hand-operated machines which we have classified as assistants to the human elements.

3.—New types of machines ; this applies mostly to the production type of tool, ingenious examples of which have appeared in recent years.

Keeping these modern tendencies in view, I propose to show you a series of lantern slides illustrating a number of the latest machine

examples of the practice in this country, also America and the Continent. Firstly, I will show some line drawings of machine detail, passing on to a few slides showing the size to which modern machines go. After that, for the purpose of keeping some order, I have divided my slides into three sections. General purpose machines such as lathes, millers, shapers, etc. Semi-production machines such as capstan, turret lathes, auto lathes. And production machines covering special purpose tools, multi-spindle automatics, etc.

(*The first of the slides, which were then shown, illustrated improvements effected, particularly as regards milling machine construction, as for example, the evolution of the over-arm, increased proportions of the knee slide, development of gearing used by a continental manufacturer, and other details. The remaining slides showed a series of well known machines possessing interesting characteristics as follows*).

Large Machine Tools.

HORIZONTAL BORING MACHINE by *H. W. Kearns*, of Broadheath, spindle diameter 10-ins. with a travel of 8-ft., height to top of head slide 21-ft., size of table 8-ft. × 12-ft. facing up to 12-ft. diameter, weight 120 tons.

A GRINDING MACHINE by *Churchill Machine Tool Company*, in a steel mill roll shop, will take rollers up to 72-ins. diameter × 10-ft. long or more, weight 24 tons upwards.

A PIPE SCREWING MACHINE by *Wagner*, to screw pipes up to 12-ins. in diameter, parallel or taper threads, compressed air chucking, quick power traverse motions and lead screw.

A LATHE by *Schiess-Defries*, to carry 75 tons on centres and admit 75-ft. between centres, six saddles with quick power motion controlled by push button, drive by 250-h.p. motor.

12-ft. × 12-ft. × 26-ft. "STIRK" HILOPLANE with fifty men on table. Note milling heads and electric control

A PLANING MACHINE in the works of *Schiess-Defries*, planing a cross rail for a large boring mill, cross rail is 60-ft. long and weighs about 90 tons.

A GEAR-CUTTING MACHINE by the *Power Plant Company*, to cut gears up to 20-ft. in diameter by 12-ft. face.

A VERTICAL BORING MILL by *George Richards*. Note the multiplicity of tool heads and the central boring column.

A VERTICAL BORING MILL by *Schiess-Defries*. Note attachment for machining propellers, desk control.

THE SCHIESS-DEFRIES HERCULES BORING MILL, believed to be the heaviest machine tool ever built, weighing 750 tons, heaviest piece the cross rail (about 75 tons). Two tables, inner 21-ft. diameter and will carry 150 tons, outer 42-ft. diameter and will carry 200 tons ; they will run both together, or with one or other stationary

drive by 250-h.p. motor. Note the desk control. The lubricating system is worthy of mention; it has its own electric-driven pumps and a tell-tale lighting system which glows if the oil is not flowing freely in all parts. Standards slide back to take 60-ft. diameter, 16-ft. 8-ins. will be accommodated under the cross rail, and by removing the standards and rail 75-ft. may be turned by out riggers. Independent motors supply power to the heads, and the rams have a vertical travel of 12-ft.

LATHE by *Holbrook*, group control on headstock, quick change gear box, form of pulley guard. Back view of same machine showing relieving attachment and taper turning slide. Note slow speed attachment in front of headstock.

EIGHT AND A HALF-INCH GAP BED LATHE by *Dean, Smith and Grace*, with electric drive and push-button control. Headstock end of same machine. Note position of motor, wide base, gear guards.

TOOL ROOM LATHE by *Lodge and Shipley*. Note wide base enclosing motor, all ground gears in headstock, speeds up to 1,000 r.p.m., clutch control from saddle, special reversing mechanism for screw cutting, chromium plated screws, feed engagement levers.

MANUFACTURING LATHE by same maker. Note stops and stop bar, also form of spindle nose.

FIFTEEN-INCH LATHE, *Schiess-Defries*, specially designed to use "Widia" metal tools, headstock all ball and roller bearings, three speeds and variable speed motor, gives 20 to 600 r.p.m., push-button control from saddle, ammeter on headstock, speed counter on saddle, centralised control of feeds on saddle, quick power traverse of saddle by independent motor, live centre.

LATHE by *John Holroyd*. Note tool used upside down to clear chips, loose head equipped with live spindle for drilling mechanical lubrication, water-cooled bearings.

BORING MILL by *George Richards*. Note controls, quick power motions, single column construction.

BORING MILL by *Schiess-Defries*. Note single column construction, proportion of side head, joy-stick control to quick power traverse motions.

DUPLEX TABLE BORING MILL by *George Richards*. Note controls, this type of machine peculiar to this country.

GRINDING MACHINE by *Churchill Machine Tool Company*. Note controls, loose head drive and table traverse changes.

GRINDING HEAD AND SLIDE, for grinding machine. Note proportions, oiling arrangements, wheel guards, water piping.

SMALL PLAIN MILLING MACHINE by *Alfred Herbert*. Roller bearing spindle, sliding gear change, plate clutch and brake. Note pulley guards, feed box with sliding gears, motor drive (easily fitted, spindle construction interesting), note roller bearings, ball thrust, flywheel type gear.

A UNIVERSAL MILLING MACHINE by *Brown and Sharpe*. Note

enclosed motor, attention line drawing (previously shown).

A PLAIN MILLING MACHINE by *J. Parkinson*. Note quick power motions, double overhead arms, spindle nose and change feed gear.

PLAIN MILLING MACHINE by *Wanderer*. Note overhead arm, form of column, water pipe construction, arm braces, jump stop motions to table, form of cutter.

POWERFUL PLAIN MILL by *Alfred Herbert*. Note overhead arm absence of universal joints, method of clamping knee, speed of quick power traverse, 150-ins. per minute.

VERTICAL MILLING MACHINE by *Brown and Sharpe*. This is the milling machine, the line drawing of which was shown among the early slides. Note extended base to accommodate the electric motor.

VERTICAL MILLING MACHINE by *Alfred Herbert*. Note grouping of change speed levers, sight feed lubricator in front of head, centralised control of feed motions and feed changes.

A SIMILAR MACHINE but of larger capacity, in which new centralised control feed box is situated in front of base. Joy-stick control and quick power motions in all directions.

PLANO MILLER by *Kendal and Gent*. Note centralised control, quick power traverse motions to all movements, horizontal and vertical heads.

ANOTHER MACHINE of same make, having two vertical heads with high speed spindles, suitable for milling aluminium. Note roller blind guard to protect slides.

SIMILAR MACHINE, using slab cutters on locomotive coupling rods.

A CUTTER GRINDER by *Alfred Herbert*. Complementary to milling machines. Note self-contained arrangement of motor drive, drive to wheel spindle by spiral gear, automatic traverse motion to table, pump and fittings for wet grinding.

GEAR-CUTTING MACHINE by *Brown and Sharpe*. Note increased proportions compared with old type machines. Fly wheel mounted on cutter spindle, push button control to self-contained motor drive.

GEAR HOBBING MACHINE by *Brown and Sharpe*. Similar general characteristics.

GEAR HOBBING MACHINE by *Barber and Colman*. Note double overhead arm and massive arm brace, large diameter hand wheel and general substantial proportions.

GEAR HOBBING MACHINE by same maker, of even heavier construction. Note overhead slide position of electric motor arrangement of quick power traverse gear and automatic return of completion of the gear.

SIMILAR MACHINE, of larger capacity. Note independent motor for operating subsidiary movements.

SPECIAL CUTTER GRINDER by *Barber and Colman*. Note self-

contained arrangement and size of machine compared with job to be done.

SPECIAL HOB GRINDER by *Barber and Colman*, which has automatic features to enable the hob to be indexed and ground without attention.

GEAR SHAPING MACHINE by *The Fellows Company*. Note compact arrangement, increased spindle diameters and speeds. Close up view rocker arm, made from Duralumin castings.

HELICAL GEAR SHAPING MACHINE by *The Power Plant Company*, using the Fellows' type cutter for cutting double helical gears. Hydraulic control to work slide, central lubrication, all gearing enclosed. Note eye bolts for lifting purposes.

GEAR CUTTING MACHINES by *Parkinson*. Note proportion of cutter slide and arbor supports, lubricating arrangements for cutters.

TYPICAL SHAPING MACHINE by *Butler Machine Company*. Note centralised control, rotary shaft, drive to table motions, rigid form of table support.

PLANING MACHINE by *Stirk*, introducing a human note. Picture shows machine at Brussels Exhibition being inspected by the King of Belgium. Note thickness of table and slides.

OPENSIDE PLANER by *Stirk*. Note electric control.

DOUBLE TABLE PLANING MACHINE by *Butler*. Tables may be run together as one unit, or separately, one table being loaded while the other is under cut. Note length of bed and general proportions.

OPENSIDE GRINDING MACHINE by *Norton Company*. Note simplicity of hydraulic control to table, convenient adjustment to grinding slide, size of base, use of magnetic chuck, water arrangements with water tank on wheels to facilitate cleaning.

VERTICAL SPINDLE SURFACE GRINDER by *Churchill Machine Tool Company*. Note form of drive, form of wheel head, centralised control to table.

SIMILAR MACHINE by *Lumsden*. Note position of motor, adjustment to wheel head, hydraulic operation to table.

ROTARY TABLE SURFACE GRINDER by *Lumsden*. Typical of a type ranging from 24-ins. diameter table to 8-ft. diameter table. Note sliding head.

SENSITIVE DRILLING MACHINE by *Alfred Herbert*. Note increased proportions, splined spindle, telescopic guard, hinged motor drive. Multiple spindle example shows drill coolant arrangement. Note open trough from table to tank.

A HEAVIER TYPE MACHINE by *James Archdale*. Note controls, balance weight case over spindle, size of table on three-spindle arrangement.

ANOTHER HEAVY TYPE DRILLING MACHINE by *Archdale*. Note centralised control, compound table, form of base.

VERTICAL DRILLING MACHINE by *Reinhold*. Note position of motor drive, centralised control, large hand wheel, splined spindle, automatic return to spindle trip motion has acted. Indicator to show spindle speed.

RADIAL DRILLING MACHINE by *Archdale*. Note centralised control position of electric motor.

RADIAL DRILLING MACHINE by *Asquith*. Note departure from accepted radial drill practice, no sleeve on column, independent motor for raising and lowering arm. Motor for spindle drive carried on drill slide ; action of engaging feed locks saddle and arm. Neat arrangement for changing feeds and speeds. Note drill knock-out. Use of supplementary tables.

RADIAL DRILL by *Kolb*. Five electric motions : (1) main spindle drive ; (2) raising and lowering arm ; (3) quick power traverse motion to saddle ; (4) column locking device ; (5) water pump. Note high spindle speeds, ammeter, revolution indicator.

HORIZONTAL BORING MACHINE by *Schiess-Defries*. Note full depth, bed, motor drive and push-button control, quick power traverse motions in all directions, inter-connected support bush on steady bracket.

A SIMILAR MACHINE by *The Union Company*. Similar general characteristics but arranged with high speed spindle for boring aluminium.

HORIZONTAL BORING, DRILLING, MILLING AND FACING MACHINE by *H. W. Kearns*. Note covered bed, facing head carrying two tools, gate change feed and speed changes. Use of graduated rules and verniers.

SIMPLE JIG BORING MACHINE by *The "Kellocater."* Note method of indexing table by electric contacts.

JIG BORING MACHINE by *Société Genevoise*. This machine is the product of the demand for accuracy, the whole reason for the machine being the production of accurate jigs.

HYDRAULIC BROACHING MACHINE. Note large dimensions sliding broach support, motor drive, quick return to ram.

SAWING MACHINES by *Wagner*. Note substantial proportions, speed of cutting, self-contained arrangement, revolving base for cutting angles ; compact arrangement of drive for saw spindle central lubricating arrangements.

HORIZONTAL FORGING MACHINE by *Schiess-Defries*. Introduced to show that the machines for rough operations are being refined. Note covered-in construction, grouped lubrication and general clean design.

Semi-Production Machines.

NO. FIVE CAPSTAN LATHE by *Alfred Herbert*. An enlarged edition of our old friend THE NO. FOUR. Note the covered bed, independent feed motions to turret and saddle ; automatic cross and longitudinal

traverse to saddle. Hexagon stop bar.

COMBINATION TURRET LATHE by *H. W. Ward*. Note independent feeds to saddle and turret, sliding gears in headstock, arrangement of water supply.

AN AMERICAN TURRET LATHE. Note general proportions.

NO. TEN COMBINATION TURRET LATHE by *Alfred Herbert*. Note general proportions, all ball and roller bearing headstock, clutch, control from three positions. Main spindle on roller bearings, independent feeds to turret and saddle : 16-ins. each. Adjustment of stock bar frictionless turret, covered bed ; increased chip clearances.

COMBINATION TURRET LATHE by *H. W. Ward*. independent feeds, etc.

LINE DRAWING OF COMBINATION TURRET LATHE by *Alfred Herbert*. Note sizes on slide.

TURRET LATHE by *Magdeburg*. With alternatively geared and hydraulic headstock ; centralised control to saddle and turret, covered beds, general proportions.

AUTO LATHE by *Alfred Herbert*. Note position of motor drive, general features of design ; use of air chuck.

AUTOMATIC TURNING MACHINE by *Monforts*. Note headstock drive, feed motion drive, arrangement of turret, arrangement of cross slide.

AUTOMATIC TURNING MACHINE by *Potter and Johnston*. Note use of hardened steel slides ; substantial proportions of turret, Texrope drive.

AUTOMATIC TURNING MACHINE by *Alfred Herbert*. Note general proportions, use of air chuck, independent cross slides, self-selecting feed motion, which changes under cut.

AUTOMATIC LATHE by *Lodge and Shipley*. Note general features, live centre to tailstock ; large water supply. Set up for machining aeroplane cylinder fins. Multiplicity of tooling.

SEMI-AUTOMATIC CYLINDRICAL GRINDING MACHINE by *Norton*. Note very substantial proportions. Arrangement of pneumatic control of tailstock and steady rest. Proportions of grinding spindle and oscillating arrangement. Grinding head slides, group control ; substantial proportions of table control gear and foot operation of tailstock.

INTERNAL GRINDING MACHINE by *Churchill Machine Company*. Details as per slide.

CYLINDER GRINDER by *The Heald Company*. Hydraulic operation to table.

ROTARY TABLE GRINDER by *Lumsden*. With duplex tables.

Production Machines.

SMALL AUTOMATIC by *Samson*. What a collection of bits and pieces.

SINGLE-SPINDLE AUTOMATIC by *Samson*. With self-contained drive.

LARGE FOUR-SPINDLE AUTOMATIC by *Schute*. Note general proportions, screw feed, no tool head.

FOUR-SPINDLE CHUCKING AUTOMATIC by *New Britain*. With rotating tools and indexing work holders. Will index up to eighteen hundred pieces per hour.

NEW BRITAIN CHUCKING MACHINE. Specially designed for crown wheels, ball bearing rings, etc. Note open end to facilitate chip clearing, massive proportions of tool slides, hydraulic operation to chuck. Form of motor drive.

MULTIPLE-SPINDLE DRILLING MACHINE by *Archdale*. Note forms of motor drive ; general proportions.

Discussion.

MR. SKIPPER : I would like to ask Mr. Fenton one or two questions. (1) Does he think that the introduction of " Widia " metal will supersede grinding for metal removing—I don't mean grinding for cylindrical work ? ; (2) does he advocate the front knee support for milling machines ? I was rather sorry that no slide was shown showing broaching against milling. Recently I have seen several excellent production jobs done by broaching which previously had been done by milling.

MR. FENTON : That is a very interesting point—will " Widia " supersede the grinding wheel for metal removing ? Well, " Widia " is not perfect yet. We have not got down to the bottom of it yet, neither have we in many instances the machine which is capable of handling it. There is one thing certain and that is that the grinding wheel manufacturer won't take it lying down. New patents are continually coming out, and so the fight will go on. " Widia " will have it for a bit and then the grinding wheel makers will get busy, and so on. Mr. Skipper no doubt refers to grinding from the black as against using a big milling cutter, but I have not had experience to answer that question—it would be a prophecy to answer it.

There are two schools for thought. Some people are relying on the increased size of their overhead arm, and general increases in the proportion of the other parts to obtain rigidity. Other people are putting in a support in front of the knee. There is one manufacturer that has a very strong patent covering this point, and a good many people are endeavouring to get round it. I have seen demonstrations on both types of machines and there appears to be little to choose between them. I am rather sorry I was unable to get some slides I particularly wished to show concerning the development of the Lincoln type of milling machine in which the

knee is practically done away with altogether, and if one dared to prophesy, this is the type that will develop in the future. I shall show a slide later on of a broaching machine. I am dealing to-night with the tendencies of machine tools and not one process against another. As Mr. Skipper says, wonderful jobs are being done by broaching and have been for several years. The broaching machine to-day compared with what it was years ago is a very different proposition—there is more power, quicker return. There is also a broaching machine standing upright.

MR. SYMES: I think we must all congratulate Mr. Fenton on giving us a very admirable summary of modern tendencies over a wide range of machine tools, and I, personally, would like to compliment him on the impartial and non-partisan way in which the lecture has been presented. Mr. Fenton has mentioned one or two points in which the user, as distinct from the manufacturer, is specially interested. Mr. Fenton dealt with automatic grinding machines, but I would like to raise the question that in addition to the automatic machines, I should like to have a little information on pneumatic and hydraulic operated machines, and on the use of the continuously variable drive to the spindle on all types of machines. It seems to me one particular direction in which machine tools have progressed the least. I was driving a car in 1914-1915 and also one of the early tanks with a continuously variable gear. It was possible to drive the car down hill at a speed of thirty-five to forty miles per hour, reverse and get a slight shock at the bottom and travel up hill backwards. I think it would be desirable in medium and large size machine tools to have continuous variation of speeds available. This is done by one or two firms, where there is an electric drive gear in which the motor supplies a variation in speed of four or five to one, and the rest of the reduction is taken by the gear. Mr. Fenton illustrates a clever way of getting rid of suds. I would like to ask him if he can show an equally clever way of removing chips, because on large machines—turret lathes—this is an ever increasing problem. Finally, I would like to ask Mr. Fenton whether one of the modern tendencies in machine tool design and manufacture is reduction in price.

MR. FENTON: Shall we answer the last question first? You ask for a patent method of removing chips from the machine, you want automatic clamping devices, etc., etc., and then you ask if the price is coming down. How can you do it? Taking the question of spindle variation, I have still got some slides to show. I have one slide which shows a turret lathe where the spindle has a variation of twenty to 1,200 r.p.m. so the makers claim, all controlled by the one handwheel (?) It is very interesting. I have seen it running but it is not perfect yet. That brings us to the question of hydraulic gear for machine tools, and I think if Mr. Symes will come to our lecture on this particular subject later in the session, he will hear

more about hydraulic transmission that I can tell him to-night. Then there is the question of getting rid of chips. It is about twenty-two years since I was in the testing bay of a certain machine tool works, where I had a bright idea about chip removing. I have tried it out, and a good many other people have tried out their bright ideas on this subject, but so far there does not seem to have been any universal success. I have shown a lathe with tool upside down and the work overhanging the bed on which the slide traverses, so that the chips fall down at the back. A large lathe has recently been supplied where the chips drop down on to a moving band, which travels down under the headstock and drops the chips into a light railway truck underneath, almost automatic but a fairly costly arrangement to instal.

MR. HOOD: There are one or two questions I would like to ask but I will be brief. We have been hearing some interesting things to-night. I notice particularly the attention that machine tool makers are giving to "safety-first" regarding the protection of the operator, but what I would like to know is what means are going to be employed for protecting the bed. We all know the tendency to drop spanners particularly on the lathe bed, and the need for protection from chips and grit that get underneath the slides. And there is another point, and that is regarding milling machines. One is particularly struck by the fact that milling machines have been strengthened in design, so that bigger and heavier cuts can be taken, but what steps have been taken for removing the cutting compound from the bed?

MR. FENTON: I will show you presently slides showing some turret lathes, in which the beds are entirely protected no matter what position of the saddle or turret. There is also a horizontal boring machine in another slide I have which shows a protected bed. Milling machine and getting rid of the water. This has always been the difficulty. (One slide in which the channels were considerably deepened was shown and having a pipe with a three-inch down flow). It is difficult to prevent splash with a job which is perhaps standing four or five inches above the table and then the cutter above that. The water is bound to come down. It would be a prophecy to say whether the knee type of machine will survive or go out in favour of the fixed knee type, but I think that on the fixed knee type there is a better chance of dealing with that particular point.

MR. PUCKNELL: Mr. Fenton has anticipated a remark which I had to make, so I will confine myself to one question. I would ask Mr. Fenton whether he has had any experience as to the length and reliability of roller bearings fitted to milling machines for intermittent cutting.

MR. FENTON: It is a little bit difficult to answer that question. To a large extent there is a new departure in the fitting of roller

bearings to the cutting spindle. I have had a machine under observation now for three years which was so fitted and has given no trouble at all in the spindle bearings. The outcome of these experiments is shown on the small milling machine where the roller bearings are fitted back and front.

MR. HERRING: I have one little criticism to make with respect to an earlier portion of Mr. Fenton's paper. Dealing with the general purpose tools—lathes. I notice that the modern tendency is to mount the guide screw in the front of the lathe. Personally, I think that we are going back somewhat. Sir J. Whitworth advocated placing the guide screw between the lathe bed. It is my experience that a general purpose lathe is called upon sometimes to do very coarse threads, and considerable twist is liable to take place. Some people get over this with a sub-head on the lathe, reducing the speed of the work. I think that the lathe made by the American Tool Works is the right way. The screw should be mounted just inside the lathe bed, where it is kept free from chips and cuttings and from getting dirtied and the machine from getting imparied.

MR. FENTON: With the guide screw inside the lathe bed there are a good many corners to be got round with the nut-operating mechanism, and that rather tends to backlash. The general idea of bringing it to the front is to get the simplest mechanism possible. The idea in the designer's mind is easier operation, and the long slide prevents the saddle from twisting. It is quite possible there is an easier way of getting over the difficulty. There are to-day still several lathes made with the leading screw down the centre of the bed.

A VISITOR: I should like to have information regarding the construction of the track underneath the big boring machine shown. Also, what is the effect on the roller surfaces in full roller bearings due to centrifugal friction?

MR. FENTON: Regarding the big boring mill, there are four tracks altogether, with one kept as far out as possible on the tables and one as near in. The chief trouble with the tracks was the question of lubrication—it was a matter of experiment for several months before it was satisfactorily solved. Just what the internal mechanism for lubrication is I cannot say. Lubricant at approximately thirty pound to the square inch is supplied on the track face. As to the question of centrifugal friction of the rollers in the full roller bearings as apart from the cage type, I cannot see that centrifugal friction is any greater with the full roller type than with the cage type. With the cage type you certainly get something that is liable to give trouble. The full roller type has greater support between the spindle and the outer race. There are a good many points for the full race as against the spaced race. Just how much ice it cuts, I cannot say. Some people are using one type and some people the other. Both types have been found satisfactory.

MR. GRIMSHAW : I would just like to ask what the advantage is on a Fellowes type gear cutter machine to bolt ten of them together as one machine ?

MR. FENTON : That is a trades union question. A man would work four or six units bolted together, but he couldn't work four or six single machines. Also the drive can be arranged by a single back shaft.

MR. LAUDER (President, Manchester Section) : I would like to know what experience you have had with regard to heavy chain transmission and if you have found that type better than belt transmission. I had certain machines under observation some years ago where the power drive was transmitted by chains and after about three months' service the chains stretched, and a firm expert in chain drives was consulted. They said that the chain was not sufficiently lubricated, and a system of lubrication was installed, but after running again for about three months the chains were found to have stretched further. The chain experts were again called in and they overhauled their system of lubrication, but after a further period of test the same fault took place. The result was that the chain drive was dispensed with and a belt drive installed, which gave satisfaction.

MR. FENTON : As far as I am concerned, chain drives are entirely satisfactory if they are properly fitted up. If the motor is properly mounted, ligned up and the chain is enclosed in an oil-tight case with continuous flow of oil in it, there is no trouble whatever size you go up to. It is not the cheapest form of drive, and I question whether the modern Tex-rope drive is not as good. Mr. Lauder really answers the question himself by stating that the machines in question were under observation a few years ago. Chain makers have progressed a good deal. A chain maker at one time would tell you that a chain two inches wide by three-quarters of an inch pitch would be sufficient, but now he would speak of a chain three inches wide and perhaps five-eighths inch pitch, duplex chain, etc. Chain makers are going ahead as well as machine tool makers.

MR. MILNER : Early in the evening you showed us a Swiss milling machine. I noticed that the gears in the column had a very narrow face. Could you give the reason, or the excuse, for it ? Also, could you give me any information as to the success or failure of inverted tooth chain for grinding wheels Tex-ropes, the use or the success of them ?

MR. FENTON : Regarding the proportions of the rigid milling machine, the column of this machine possibly looks light, but in this case the manufacturers rely for rigidity largely on their patented knee support, which is situated in the front of the knee, taking a large proportion of its weight. The proportions of the gears in this machine are interesting and show what can be done with modern gears running at a high speed. It is the designer's idea and I am

not here to criticise whether it is right or wrong. It is certainly giving satisfaction to many people, and I think it is largely a question of choice whether you use small gears at high speeds or larger gears at more moderate speeds. If one considers the gearbox fitted to a modern motor cycle, one can then form some idea of the power that can be put through comparatively tiny gears. Tex-ropes or chain drive for grinding wheel spindles. I think this is a question of looking rather at what the leading manufacturers of grinding machines are doing. I don't know of any substantial machines that have been built at the present time with chain drive to the spindle. I may be wrong. As far as I know there are no chain drive grinders of any importance being made. The essential point is that a grinding spindle has to rotate with as perfect turning motion as possible without vibration. Now if you have got a belt running over a pulley, you have a fairly even torque. If you get the chain drive with link space, it is perfectly impossible to detect a tap but it is there. When you come to finish work of the very highest class, take, for instance, printing roller cylinders, where you have to get a mirror finish, your spindle has got to be absolutely it, and your drive has to be absolutely it. I have seen people have trouble and that trouble has been cured solely by taking off the belt which has been on the machine and replacing by an endless belt.

MR. ECKERSLEY: I would like some details of the construction of the lathe, in which tools were used working upside down. Have you had any experience in this connection ?

MR. FENTON: That machine is an experimental one. It is especially designed for cutting upside down. The lift of the saddle has been particularly taken care of by the size and proportions of the slides and the method of adjusting them. The bed is made of special section and the saddle is provided with gibs to take up any tendency to lift, which is not the case in the ordinary lathe, gibs only being provided to take up twist. This machine is an experiment which we shall all watch with interest.

MR. SKIPPER: The time is rapidly going on, so my remarks now will be very brief. There is one thing that I have been asked to mention and that is that the Manchester Section of the Institution of Production Engineers is the last Section which has been formed. We are all very anxious that this section should prove one of the best sections of the Institution, and, naturally, we want as many new members as we can possibly get. If there are any gentlemen here who contemplate joining the Institution of Production Engineers, we should be pleased if they would see the Secretary, who is here to-night, and he will let them have the information they want if they will leave their names and addresses. I have pleasure now in asking Mr. Hood to propose a vote of thanks to the lecturer and also asking Mr. Pucknell to second this vote.

MR. HOOD: It has been a very interesting and educational lecture. I think MR. FENTON has almost convinced many of us here, in spite of Mr. Symes, of the justification of the fact that prices are rather going up than coming down. This is a subject of which we have only just approached the fringe. There are many more questions and many more points that might be raised in one form or another, and I, personally, would like to see a few more lectures of this kind, as I think that the questions that are asked and the discussion which takes place are far more beneficial than the lecture itself. I have every pleasure in proposing a very hearty vote of thanks for a very interesting and educational lecture.

MR. PUCKNELL: It gives me very great pleasure in seconding this vote of thanks.

MR. SKIPPER: It has been impossible to carry on the discussion to the length which I think it could be carried, and if it would be of interest to you we are quite prepared to arrange another night so that the discussion can be carried on.

The vote of thanks was adopted with acclamation.

MR. FENTON: I am sorry it was necessary to limit the lecture. The subject covers such a vast field that it is difficult to know what to leave out. I have many more interesting slides, and if Mr. Skipper and any members in the audience would like to carry on the discussion, I should be very pleased to negotiate with the Secretary with a view to arranging this. I thank you, Gentlemen, for the way in which you have received the lecture.